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(54) REGENERATION OF HYDROCARBON CRACKING CATALYST

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The invention relates to a process and apparatus for oxidative regeneration of used catalyst for cracking hydrocarbon feed stocks.

What is desired is a process and apparatus which ensure a maximum degree of catalyst regeneration, that is minimization of residual coke on catalyst and uniformity of regeneration of catalyst particles.

The invention provides a process for oxidative regeneration of used catalyst for cracking of hydrocarbon feed stocks, comprising performing a first regeneration stage in an upflow of fluidized catalyst with co-current flow of regenerating gas and catalyst, and performing a second regeneration stage in a fluidized bed with cross flow of regenerating gas and catalyst at a lower gas velocity than in the first stage.

The invention also provides apparatus for carrying out the process, comprising a cylindrical casing having a sleeve in the bottom portion thereof which constitutes, together with the casing, an annular chamber, the top portion of the interior space of the sleeve being in communication with the annular chamber; a cyclone separator and a duct for removal of flue gas provided at the top of the casing; at least one radially extending vertical baffle in the annular chamber; means for introducing used catalyst into the sleeve; outlet means for removing regenerated catalyst from the annular chamber; and gas distribution arrangements for introducing regenerating gas into the sleeve and the annular chamber.

Fresh regenerating gas is preferably fed separately to each stage. This ensures reliable control of the degree of regeneration at each stage of the process.

The used catalyst is preferably fed directly to the upflow of fluidized catalyst in the first stage of the process. This enables the addition of used catalyst to a predetermined fluidized zone exclusively. In addition, with

this mode of catalyst feeding, the dust load of the gas flowed and the duty of the cyclone is relieved.

The second stage or regeneration is preferably conducted by passing the partially regenerated catalyst through a plurality of fluidized bed sections. This ensures an increase in the average rate of coke burning-off at the second stage of the process, improves the degree of regeneration and uniformity of burning-off coke on the catalyst particles.

If the apparatus for carrying out the process has a single baffle in the annular chamber, this baffle should preferably be solid, the top portion of the sleeve being provided with at least one through-slot for the catalyst passing into the annular chamber, and the baffle preferably being arranged between the slot and the outlet means in such a manner that the slot and the outlet means are immediately adjacent to the baffle. This design prevents the catalyst from escaping directly from the sleeve to the outlet means for removal of regenerated catalyst; thus it is impossible for partially regenerated catalyst to be removed from the apparatus.

The annular chamber of the apparatus should preferably have several radially extending vertical baffles having apertures for overflow of catalyst, these apertures being arranged alternately at the top and bottom. Alternatively, the baffles may be made shorter alternately at the top and bottom. One of the baffles is preferably made solid.

This arrangement minimizes the adverse effect of catalyst stirring in the fluidized bed of the annular chamber, i.e. in the second stage of regeneration, results in an increase in the average rate of burning-off coke, and improves the uniformity of regeneration of individual catalyst particles.

The sleeve may be flared at the top. This results in a lower velocity of gas and catalyst at the top of the sleeve, thereby reducing the catalyst entrainment from the sleeve and the possibility for the catalyst particles to get from the sleeve to any random point of the fluidized bed in the annular chamber. Furthermore, the conditions for overflow of fluidized catalyst from the top of the sleeve are improved. The top of the sleeve may be provided with a solid cover plate. This completely eliminates the loss of catalyst upwards from the top of the sleeve, all the catalyst being removed from the sleeve to the annular chamber only through the slot or slots at the top of the sleeve.

The invention will now be described further with reference to specific embodiments thereof diagrammatically illustrated in the accompanying drawings, in which:

Figure 1 shows a general view of the apparatus for carrying out oxidative regeneration of used catalyst for cracking of hydrocarbon feed stocks;

Figure 2 is a general cross section of the apparatus with a single solid baffle in the annular chamber;

Figure 3 is a general cross section of the apparatus with several radially extending vertical baffles in the annular chamber;

Figure 4 shows in perspective an embodiment of radially extending vertical baffles having apertures;

Figure 5 shows in perspective an embodiment of radially extending vertical baffles made shorter alternately at the top and bottom;

Figure 6 is a perspective view of an embodiment of the sleeve flated at the top;

Figure 7 shows in perspective a possible embodiment of the arrangement of the duct for feeding the used catalyst from a reactor to the apparatus; and

Figure 8 shows another possible embodiment of the arrangement of the duct for feeding the used catalyst from the reactor to the apparatus.

The oxidative regeneration of used catalyst for cracking of hydrocarbon feed stocks is carried out in two stages.

Used catalyst from a reactor is directly fed to the first stage of regeneration, i.e. to an upflow of fluidized catalyst (as shown by arrows A in Figures 1, 7 and 8). Fresh regenerating gas is fed to the same point (as shown by arrows B in Figures 1, 7 and 8). In the first stage of regeneration the process is carried out in an upflow of fluidized catalyst under the conditions of co-current contact of regenerating gas and catalyst, the gas and catalyst being fed to the bottom and removed from the top of the fluidized bed.

High linear velocity of gas flow is maintained, at which gas bubbles are unstable, and a sufficiently uniform diluted fluidized bed is formed. This facility ensures a high efficiency of contacting the regenerating gas and used catalyst.

The catalyst partially regenerated in the first stage is fed for further regeneration to the second fluidized bed (see arrows A in Figures 1 and 8). In the second stage of regeneration, the catalyst flows over the fluidized bed in the direction indicated by arrow A (Figure 1) at right angles to the upflow of fresh regenerating gas indicated by arrows B. Thus, the second-stage regeneration is performed in a crossflow of regenerating gas and catalyst, and all catalyst particles travel along the full length of the fluidized bed from the point of entrance to the point of emergence from the bed. This results in maximum residence time of particles in the fluidized bed and uniform regeneration of individual particles.

In order to reduce mixing of catalyst par-

ticles and increase the rate of regeneration, the second stage is preferably performed by successively passing regenerated catalyst through a number of fluidized beds, with fresh regenerating gas being fed to each fluidized bed in parallel streams.

Velocity of gas in the fluidized bed in the second stage is lower than that in the upflow of fluidized catalyst in the first stage. Therefore, in the second stage the fluidized bed is more dense. However, to provide for higher efficiency of contacting regenerating gas and catalyst in the fluidized bed in the second stage, sufficiently high velocity of gas should be maintained.

Fresh regenerating gas is fed separately to each stage of the process (see arrows B in Figures 1 and 8). After passing through each fluidized bed, the used gas streams are combined in a settling zone and removed in a single stream from the apparatus (arrows B in Figure 1).

Regenerated catalyst is removed from the fluidized bed of the second stage as shown by arrows A (Figures 1 and 8) from the point remotest from the point of admission of partially regenerated catalyst to this fluidized bed.

The process for oxidative regeneration of used catalyst will be discussed in more detail below in the description of the apparatus for its implementation.

The apparatus comprises a cylindrical casing 1 having a coaxial sleeve 2 in the bottom portion thereof which constitutes together with casing 1 an annular chamber 3.

Ducts 4 and 5 for admission of regenerating gas to the sleeve 2 and the annular chamber 3, respectively, are arranged at the bottom of the casing 1. In the specific embodiment of Figure 1, the duct 4 for admission of regenerating gas to the sleeve 2 is also used for charging the used catalyst into the apparatus. In this embodiment, the gas distribution arrangements comprise a perforated grid 6 in the sleeve 2 and a tubular distribution 7 in the annular chamber 3.

At least one dip leg 8 for removal of regenerated catalyst from the apparatus extends into the annular chamber 3 and is located at such a point in the annular chamber 3 as to provide for maximum travel of catalyst particles in the annular chamber 3.

The top of the casing 1 accommodates cyclones 9 for cleaning the flue gas of catalyst fines and a flue gas exhaust duct 10.

Figure 2 is a cross sectional view of the apparatus, which in this particular embodiment has a single vertical baffle 11 extending radially in the annular chamber 3. The single vertical baffle has no apertures. The top portion of the sleeve 2 has one or more through-passing slots 13 for massive removal of partially regenerated catalyst to the annular chamber 3. The baffle 11 is arranged between the slots 13 and dip leg 8 in such a manner that slots 13 and the dip leg 8 are immediately adjacent thereto. The slots 13 may be of any desired shape, preferably rectangular. The dimensions and number of slots 13 depend on the amount of catalyst passing through the apparatus.

The solid baffle 11 prevents the partially regenerated catalyst from passing directly from the slots 13 to the dip leg 8 and bypassing the annular chamber 3 after leaving the sleeve 2.

To increase the average rate and degree of catalyst regeneration, the annular chamber is preferably divided into sections, which is achieved by using therein a number of radially extending baffles 12 (Figure 3). The baffles 12 have apertures 14 (Figure 4) for overflow of fluidized catalyst from one section 17 to another. The apertures 14 are preferably made alternately at the top and bottom of baffles 12. The apertures 14 are of any desired shape. The dimensions and number of apertures 14 depend on the flow rate of catalyst.

Instead of using apertures 14, the baffles 12 may be made alternately shorter at the top and bottom (Figure 5). The arrangement of the apertures 14 alternately at the top and bottom of the baffles 12, or making the baffles 12 alternately shorter at the top and bottom lengthens the travel path of catalyst within the fluidized bed sections and improves the uniformity of regeneration of individual catalyst particles. When there are several sectioning baffles, the baffle 11 between the slots 13 of sleeve 2 and the dip leg 8 is preferably made solid (Figures 3, 4, 5).

The sleeve 2 may be of any desired type. It may be flared at the top (Figure 6). The sleeve 2 may also be closed by a solid cover plate 16 (Figure 1). A flared shape of the sleeve 2 contributes to lowering of the gas velocity, and, hence reduces the entrainment of catalyst to the settling zone at the top of the casing 1. Lowering gas velocity also improves the conditions for overflow of fluidized catalyst through the slots 13 to the fluidized bed in the annular chamber 3. The solid cover plate 16 completely eliminates the entrainment of catalyst from the sleeve to the settling zone.

Depending on the relative arrangement of the reactor and regeneration apparatus, the duct for introduction of used catalyst into the apparatus may be located at various points.

In the embodiment shown in Figure 1, the duct 4 is used to introduce the used catalyst from the reactor, as well as fresh regenerating gas, into the sleeve 2.

Figure 7 shows an alternative arrangement of a duct 18 for introduction of used catalyst to the apparatus. The duct 18

extends through the casing 1, the annular chamber 3, and the wall of the sleeve 2 and terminates just above the gas distribution arrangement 6 of the sleeve 2.

Still another embodiment (Figure 8) involves the arrangement of the duct 18 axially in sleeve 2. The duct 18 again terminates just above the gas distribution arrangement 6 of the sleeve 2. The amount of used catalyst passing through the duct 18 may be controlled by means of a valve (not shown).

The apparatus described above functions in the following manner.

Used catalyst from the reactor is fed through the duct 4 (Figure 1) or the duct 18 (Figures 7 and 8) to the fluidized bed in the sleeve 2 as shown by arrows A. Fresh regenerating gas is also fed to the same point through the duct 4 and the gas distribution grid 6 as shown by arrows B. In the specific embodiment shown in Figure 1, the catalyst is carried to the apparatus by fresh regenerating gas. The catalyst and regenerating gas enter sleeve 2 through the duct 4 and the gas distribution grid 6. In the other embodiments shown in Figures 7 and 8, the catalyst is fed from the reactor to the sleeve 2 by gravity.

The first stage of regeneration of used catalyst is performed in the sleeve 2. The process of regeneration occurs in the upflow of fluidized catalyst with co-current contact of regenerating gas and catalyst. The process of regeneration in the first stage is performed at 540 to 760°C (preferably from 630 to 690°C) and under a pressure of 0.05 to 3.5 atm. gauge. High linear velocity of gas, 0.6 to 10.0 m/s (preferably 1.0 to 2.5 m/s), is maintained to facilitate the formation of a diluted fludized bed with a solids content of 30 to 300 kg/m^3. With high gas velocities in the diluted fluidized bed, gas bubbles become unstable, and the fluidized bed exhibits so-called "secondary uniformity". In such cases, gas is in more efficient contact with the catalyst. The gas distribution grid 6 at the bottom of sleeve 2 should offer a sufficiently high drag so as to ensure uniform distribution of the gas stream over the cross-section of sleeve 2. This, in turn, contributes to more efficient contact of the regenerating gas and the catalyst.

The catalyst partially regenerated in the first stage of the process escapes through the slots 13 at the top of sleeve 2 into the fluidized bed in the annular chamber 3 (arrows A). Owing to the high linear velocity of gas in the upflow of fluidized catalyst in the sleeve 2, individual particles of the catalyst may be thrown in to the fluidized bed in the annular chamber 3 over the edge of sleeve 2, by-passing the slots 13. This may result in a shorter residence time of particles in the fluidized bed in annular chamber 3, and hence in non-uniform regeneration of catalyst particles.

Flaring the top portion of sleeve 2 (Figure 6) results in lowering of gas velocity, thus improving the conditions for overflow of fluidized catalyst through the solts 13. The cover plate 16 of sleeve 2 completely eliminates the entrainment of catalyst from sleeve 2 to the settling zone of the apparatus, and the entire stream of fluidized catalyst is fed through the slots 13 to annular chamber 3.

The second stage of regeneration is performed in the fluidized bed in the annular chamber 3. Here the stream of fluidized catalyst is mainly directed from the point of its admission (through the slots 13 of the sleeve 2) towards the inlet of dip leg 8 (Figures 2, 3). Solid catalyst particles travel over the full path along the entire circumference of the annular chamber 3. This is facilitated by the provision of the solid baffle 11 between the slots 13 of the sleeve 2 and the dip leg 8 for removal of regenerated catalyst, immediately adjacent to the slots. Fresh regenerating gas fed to the annular chamber 3 through the gas distributor 7 (Figures 1, 7, 8) passes upwardly through the fluidized bed (arrows B). Therefore, the directions of the catalyst (arrows A) and gas (arrows B) streams are at right angles to one another, i.e. there is a crossflow of catalyst and regenerating gas.

The second stage of regeneration of catalyst is performed at 560 to 765°C (preferably from 630 to 700°C), and under the same pressure as in the first stage. Linear velocities of gas in the fluidized bed are lower than those in the upflow of fluidized catalyst in the first regeneration stage, being from 0.3 to 2.5 m/s (preferably 0.7 to 1.2 m/s). With such gas velocities, the solids content of the fluidized bed is 100 to 600 kg/m^3, i.e. greater than that in the upflow of fluidized catalyst in the first stage of the process, and thus the fluidized bed is more dense here.

In the second stage of the process of regeneration, the linear velocity of gas is also preferably maintained at a sufficiently high level so as to improve the efficiency of contact of regenerating gas and catalyst. In order to reduce the adverse effect of catalyst mixing in the fluidized bed in the annular chamber 3, i.e. in the second regeneration stage, the partially regenerated catalyst is successively passed through a number of fluidized bed sections (Figure 3), fresh regenerating gas being fed to each fluidized bed section. The number of fluidized bed sections depends on the regeneration conditions. Conducting the second stage of regeneration in a partitioned fluidized bed provides most favourable conditions for deep and uniform regeneration of catalyst.

After leaving the sleeve 2, the fluidized

catalyst passes through the annular chamber 3 divided into sections by the vertical baffles 12, successively from one section to another, towards the dip leg 8 (Figure 3). The solid baffle 11 prevents the partially regenerated catalyst from breaking through the sleeve 2 directly to the dip leg 8. Fluidized catalyst overflows from one section to another either through the apertures 14 arranged alternately at the top and bottom of the baffles (Figure 4) or alternately over and under the baffles (Figure 5).

Regenerated catalyst is removed from the apparatus through one or more dip legs 8 arranged in the annular chamber 3. The dip legs 8 are arranged near solid baffle 11 on the side opposite to slots 13. When the annular fluidized bed is divided into sections, the dip legs 8 are arranged within the last fluidized bed.

After passing through the fluidized beds in both regeneration stages, the used flue gases are combined in the settling zone above the fluidized beds and fed as a single stream in to the cyclones 9 where they are separated from entrained catalyst fines. Cleaned gas leaves the apparatus through the pipe 10, and catalyst fines are returned to the fluidized bed in annular chamber 3 through the dipleg 19 of the cyclones 9.

Therefore, the above-described apparatus ensures high efficiency of the process for oxidative regeneration of used catalyst for cracking of hydrocarbon feed stocks, i.e. a high degree of regeneration. The burning-off of coke is intensified, and catalyst load in the apparatus is lowered.

WHAT WE CLAIM IS:-

1. A process for oxidative regeneration of used catalyst for cracking of hydrocarbon feed stocks, comprising performing a first regeneration stage in an upflow of fluidized catalyst with co-current flow of regenerating gas and catalyst, and performing a second regeneration stage in a fluidized bed with crossflow of regenerating gas and catalyst at a lower gas velocity than in the first stage.

2. A process as claimed in claim 1, wherein fresh regenerating gas is fed separately to each stage.

3. A process as claimed in claim 1 or 2, wherein used catalyst is fed directly to the upflow of fluidized catalyst in the first stage.

4. A process as claimed in any of claims 1 to 3, wherein the second stage is performed by passing the partially regenerated catalyst through a plurality of fluidized bed sections.

5. Apparatus for carrying out the process claimed in claim 1, comprising: a cylindrical casing having a sleeve in the bottom portion thereof which constitutes, together with the casing, an annular chamber, the top portion of the interior space of the sleeve being in communication with the annular chamber; a cyclone separator and a duct for removal of flue gas provided at the top of the casing; at least one radially extending vertical baffle in the annular chamber; means for introducing used catalyst into the sleeve; outlet means for removing regenerated catalyst from the annular chamber; and gas distribution arrangements for introducing regenerating gas into the sleeve and the annular chamber.

6. Apparatus as claimed in claim 5, wherein the annular chamber has a single solid baffle, the top portion of the sleeve being provided with at least one slot for removal of catalyst to the annular chamber, the baffle being arranged between the slot and the outlet means, the slot and the outlet means being immediately adjacent to the baffle.

7. Apparatus as claimed in claim 5, wherein several radially extending vertical baffles are provided in the annular chamber, dividing the chamber into sections, the baffles being adapted to allow overflow of catalyst from each section to the next.

8. Apparatus as claimed in claim 7, wherein the baffles have apertures arranged alternately at the top and bottom.

9. Apparatus as claimed in claim 7, wherein the baffles are made alternately shorter at the top and bottom.

10. Apparatus as claimed in claim 7 or 8, wherein one of the baffles is made solid.

11. Apparatus as claimed in any of claims 5 to 10, wherein the sleeve is flared at the top.

12. Apparatus as claimed in any of claims 5 to 11, wherein the top of the sleeve is provided with a solid cover plate.

13. A process for oxidative regeneration of used catalyst for cracking hydrocarbon feed stocks, substantially as described herein with reference to the accompanying drawings.

14. Apparatus for carrying out oxidative regeneration of used catalyst for cracking of hydrocarbon feed stocks, substantially as described herein with reference to, and as shown in, the accompanying drawings.

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1562571 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

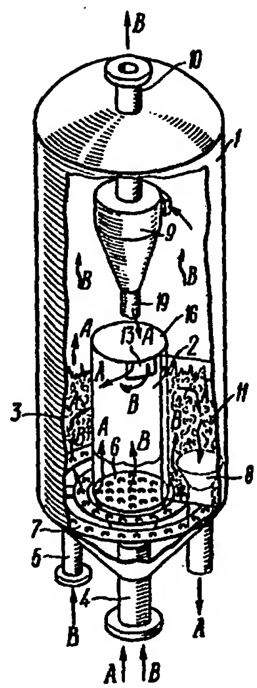

FIG. 1

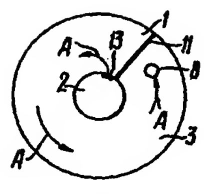

FIG. 2

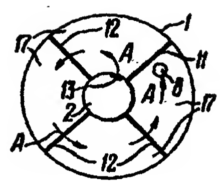

FIG. 3

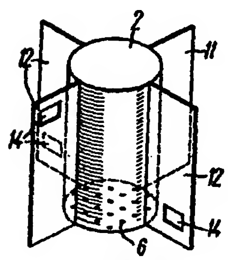

FIG. 4

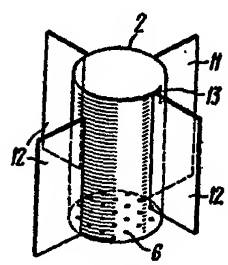

FIG. 5

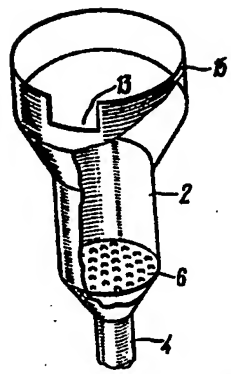

FIG. 6

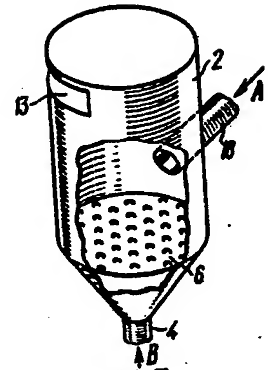

FIG. 7

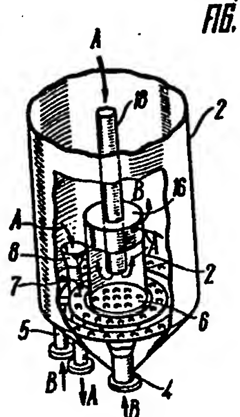

FIG. 8